Cooling and Amplifying Mechanical Oscillators with Light

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Recent years have witnessed a series of developments at the intersection of two, previously distinct subjects. Optical (micro-) cavities [1] and micro (nano-) mechanical resonators [2], each a subject in their own right with a rich scientific and technological history, have, in a sense, become entangled experimentally by the underlying mechanism of optical, radiation pressure forces. These forces and their related physics have been of major interest in the field of atomic physics for over 5 decades [3-5], and the emerging opto-mechanical context for these forces has many parallels with this field. There is also a rich theoretical history that considers the implications of optical forces in this new context [6-9]. Despite this theoretical promise, the manifestations of these forces on micro-mechanical objects have only recently become an experimental reality [10]. We will review recent demonstrations of both mechanical amplification and cooling by radiation pressure forces in a micron-scale toroidal resonator [11]. These devices contain high-Q optical modes (Q factors as high as 500 million) in coexistence with high-Q mechanical breathing modes. Resonantly enhanced optical forces couple these mechanical and optical degrees of freedom, creating two distinct dynamical regimes. In the first, mechanical amplification can overcome intrinsic loss to induce regenerative oscillation up to microwave rates [12]. In the second, mechanical cooling to low temperatures is possible (10K from room temperature has been demonstrated in toroidal resonators). After reviewing recent progress concerning mechanical cooling in toroidal and other resonator geometries [13,14], the possible future directions of this emerging field of *cavity opto-mechanics* will be considered.

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